

## **GPS Based Guidance Systems for Agriculture**

**Jess Lowenberg-DeBoer**  
**Purdue University**

### **Introduction**

Global Positioning System (GPS) guidance for ground based application equipment in agriculture is being adopted rapidly. Among other benefits, these systems help operators reduce skips and overlaps in applying fertilizer, pesticides and other inputs. In the last two years, use of the GPS guidance for ground equipment has gone from almost nothing to about 5% of all custom fertilizer and pesticide application equipment in the US. Crop producers are also starting to use the systems.

"It is our hottest item right now," said Curtis Schaben, Ag Leader, Ames, Iowa. "Especially for larger operators, with large areas of drilled soybeans. Many already have GPS to use with yield monitors. They are looking for other GPS uses."

"We also sell a lot in Western Canada where fields are large and air seeders are popular. It can be very dusty there at seeding time and the GPS keeps them on track in the dust."

GPS guidance systems can be used for all types of agricultural operations: planting, spraying, fertilizer spreading, tillage. Potentially, they replace the foam and disk marker systems now used to guide operations.

In its most basic form GPS guidance is a horizontal "lightbar" in a plastic case 12 to 18 inches long linked to a GPS receiver. The operator watches a bar of light. If the light is on the center line the machine is on target. If a bar of light extends to the left, the machine is off the swath to the left and needs to be corrected. If a bar of light extends to the right, the machine is off to the right. The lightbar can be mounted inside or outside of the cab. Similar GPS guidance systems have been used for aerial application since the early 1990s. While innovators in the use of GPS guidance for agriculture often have experience in using GPS for variable rate application and yield monitoring, GPS guidance is often used just to improve accuracy and speed of uniform application.

More advanced systems have a screen showing the swath of the machine as it moves through the field. Early models only allowed straight line parallel swaths, but now software is available for any contour. Areas covered with previous swaths are marked on the screen. These systems have the capacity to generate "as-applied" maps showing what part of the field was covered and the application pattern.

## GPS vs. Foam Markers

The largest community of GPS guidance users in agriculture is in the custom fertilizer and pesticide application business. According to Art Lange, Trimble Navigation, Sunnyvale, California, about 80% of new GPS guidance systems for ground based application equipment in agriculture in the U.S. and Canada are used for custom work. The guidance alternative for this group is foam markers. This community of users has generated several lists of GPS advantages (Buick and White, 1999; Geofocus, 1999; Juncker, 1999). Advantages include:

- ③ **GPS parallel swathing is more reliable and more accurate than foam markers** - Scott Azbell, Agro-Chem, Wabash, Indiana, said that with foam markers on average about 10% of the field area is either skipped or overlapped. With GPS that skip and overlap rate drops to about 5%. Some tests have shown that with an experienced operator, the skip and overlap rate with GPS can be as low as 1.5%.
  
- ③ **GPS guidance allows accuracy at higher speeds** - A test done in New Zealand showed a 13% higher speed with GPS guidance than with a foam marker (Buick and White, 1999). A similar test in California showed a 20% higher speed.
  
- ③ **With spinner spreaders GPS guidance is the only possibility** - Azbell said foam markers can not be used effectively with spinner spreaders. There is no boom for the foam equipment to be installed on. Because of the spread width, a foam marker in the center of the machine path is difficult to see from the next swath.  
  
"One of the forces driving GPS guidance in our area is dry application, especially lime," Azbell said. "Variable rate lime to manage pH is a proven practice. Lime is applied with spinner spreaders which can't use foam markers."
  
- ③ **GPS guidance is easy to use** - Younger operators learn faster than older operators, because they are more accustomed to computer use, Azbell said. But even the older operators learn quickly.  
  
"Sometimes I send older operators home with an assignment to play computer games for an evening," Azbell said. "After that they aren't scared of the computer and learn quickly."
  
- ③ **GPS provides effective guidance over growing crops** - With solid seeded crops, the foam tends to fall through the canopy to the ground where it is almost invisible. GPS is not affected by the crop height.

- ③ **GPS guidance allows operation when visibility is poor** - GPS guidance works at night, in dust or fog. This lengthens working time during critical planting and spraying periods. In many areas nighttime is the best for spraying because of low wind speed.
- ③ **GPS guidance is less affected by weather** - In some semi-arid areas low humidity, heat and large field size combine to make foam markers ineffective. The foam sometimes evaporates before the operator makes the return swath. GPS guidance works at low temperatures, when foam systems freeze.
- ③ **GPS guidance has lower recurring costs** - GPS guidance have no moving parts or tubes to clog. Depending on the manufacturer, software updates for GPS guidance are usually free to system owners. Current GPS guidance technology will almost certainly be eclipsed by new technology before it is worn out. Foam marker systems require foam, dye and tank cleaner.

The primary recurring cost for GPS guidance is satellite differential correction which costs about \$800/yr/GPS unit. For many custom operators the differential correction fee is less than the cost of foam. For example, depending on settings and ground speed one gallon of foam will mark 150 to 300 acres. Foam prices range from \$16 to \$21 per gallon. For a custom operator who covers 20,000 acres per year this means a cost for foam alone of \$1200 to \$2800.

Many producers already have GPS for yield monitoring and pay a differential correction fee. For them GPS guidance has almost no recurring costs. According to Schaben, it is possible to use GPS guidance with Coast Guard beacon differential correction and that this may be adequate for some applications, like application of dry fertilizer with a spinner spreader. Azbell said that for custom spraying the 6 inch (10 centimeter) accuracy is preferred.

- ③ **GPS guidance reduces operator fatigue and eye strain** - With the lightbar mounted directly in front of them, GPS guidance operators do not need to look backward or sideways. They can drive accurate swaths while looking straight ahead.
- ③ **GPS guidance has lower set up time** - Foam markers have tanks that must be filled and dyes that need to be changed. GPS guidance begins working approximately 30 seconds after the machine is switched on.
- ③ **GPS guidance is not affected by wind or boom bounce** - Blowing foam or a foam system bouncing at the end of a long boom over rough ground may introduce substantial error.

- ③ **GPS guidance reduces chemical use, by reducing overlaps** - If that 10% overlap is reduced to 5%, chemical use is also reduced by 5%, which is good for the environment, as well as for the bottom line.
  
- ③ **As-applied maps can be used for quick and accurate billing** - Many systems allow the user to calculate acreage covered. Maps can be included in billings to show what has been done. According to Jim Wheeler, INSAT, Flanagan, Illinois, wireless transfer systems are being developed which would automatically send as applied maps to the home office and trigger billing as soon as a field was finished. Azbell suggests that the maps may also be useful in settling liability questions and insurance claims.
  
- ③ **GPS guidance reduces need to enter already sprayed areas** - According to Steve Hawkins, Assistant Director of Purdue University Agricultural Centers, GPS guidance allows the operator to mark where spraying stopped, for instance if the tank was empty or because of a breakdown, without dismounting.

"After you have sprayed you really should not be in that field without protective gear," Hawkins said. "If you go to fill the tank, the foam will have evaporated by the time you return. Before GPS at best a person could throw a flag out the window. GPS allows you to mark the spot and come back to it."

## **GPS Guidance Cost**

The most frequently mentioned disadvantage of GPS guidance is the up-front cost which ranges from about \$3000 for a farmer who already has a GPS to over \$14,500 for a custom applicator. A basic system with GPS and lightbar can be purchased for about \$7000. According to Azbell the biggest differences between the farmer and custom systems are speed, screen display and the ability to provide as-applied maps.

"Some of the cheaper GPS guidance units that you see advertised are slow. It is like using a computer with 286 chips," Azbell said. "They are also strictly lightbar units, with no screen display or map making ability."

Foam marker systems purchase prices range from \$900 to \$2,800. According to Azbell speed is also an issue in foam systems. The lower cost foam systems are slower and work ok when application is done with a tractor. Commercial applicators operating at 20 mph need more foam output than the lower cost systems can provide.

The useful life of the GPS units is hard to estimate because of the short period that they have been on the market, but Azbell said that he recommends that users try to recover costs in three years. Foam marker systems often last about five years or more, Azbell said

“The GPS guidance system will work longer than three years, but by that time it will probably be obsolete.” Azbell said. “It will still do everything you originally wanted it to do, but something much better will be on the market.”

Cost and benefits vary widely depending on the crop, acreage covered, swathing accuracy achieved and other factors. Table 1 provides examples of GPS guidance costs and benefits for four scenarios: producer buy a whole system including GPS and lightbar, producer who already has a GPS, custom operator who buys a GPS guidance system with screen display and capacity to generate as applied maps and a custom operator who installs GPS guidance, but makes do without the screen and map making ability.

The first three scenarios show GPS guidance as increasing per acre costs. The per acre costs almost double for the producer who already has a GPS and for the custom operator with a complete system. For the producer starting from scratch guidance costs increase by a factor of 6. Only for the custom operator who can make do with the basic GPS guidance are costs reduced. This means that for many potential users the key to determining the profitability of GPS guidance is on the benefit side.

The benefits estimated in Table 1 focus on only the opportunity cost of sprayer operation and the cost of extra chemical and fertilizer. Azbell's estimate of the percentage overlap is used, 10% with foam markers and 5% with GPS guidance. For simplicity the example assumes that the operators are very cautious and make only overlaps, no skips.

“Operators tend to overlap more than they skip in order not to show the obvious misses to the farmer's eye,” said Roz Buick, Trimble Navigation, Christchurch, New Zealand. “When watching the foam marker at the end of the boom the tendency to overlap is greater than to skip.”

The machine cost of overlaps is estimated at the custom rate, \$4.40/a for producers with tractor units (Doster, 1998) and \$5/a for commercial custom application. Custom application is a highly competitive business with low profit margins. In most cases the custom application rate is a good estimate of labor and machine costs including depreciation, fuel, lubricant and repairs. For the custom applicator the custom rate is what the applicator would earn if the operator and machine were out doing another field instead of overlapping swaths.

The estimation of the economic impact of skips is complicated because the effect of crop yield varies by crop, the weed population and how long term weed seed bank effects are valued. A skip is much more costly in a higher value crop, such as sugar beet, potatoes, or seed crop, than it would be in bulk commodity corn, soybeans and wheat. If the skip occurs in a very clean field, the yield effect may be minimal, but in a heavily infested field the yield may drop to almost zero. Weed scientists suggest that the greatest economic effect of skips may be on creating a seed bank that will lead to management problems in future years (Cupery, 1987).

Table 1. Cost and Benefit Examples for GPS Guidance and Foam Markers for Use by Producers and Custom Applicators.

Item	Producers-----			Custom Applicators-----		
	Foam Marker	GPS Guidance	Lightbar Only	Foam Marker	Only GPS Guidance	GPS Guidance
Costs:						
Purchase Price, \$	\$1000	\$7000	\$3000	\$3000	\$7000	\$14,500
Useful Life, years	5	3	3	5	3	3
Annualized Cost, \$.yr <sup>1</sup>	\$264	\$2815	\$1206	\$765	\$1847	\$5831
Recurring Cost:						
Foam, \$.yr <sup>2</sup>	\$336	0	0	\$2940	0	0
Differential						
Correction, \$/yr	0	\$800	0	0	\$800	\$800
Annual Cost, \$.yr <sup>3</sup>	\$600	\$3615	\$1206	\$3705	\$2647	\$6631
Annual Cost, \$/a/yr <sup>4</sup>	\$0.20	\$1.20	\$0.40	\$0.17	\$0.13	\$0.33
Benefits in Reducing Overlap:						
Percent of Area Overlapped	10%	5%	5%	10%	5%	5%
Overlap Acres	300	150	150	2000	1000	1000
Opportunity Cost						
Operation						
\$/a <sup>5</sup>	\$4.40	\$4.40	\$4.40	\$5.00	\$5.00	\$5.00
\$/yr	\$1320	\$660	\$660	\$10,000	\$5000	\$5000
Extra Chemical and Fertilizer, \$.yr <sup>6</sup>	\$3000	\$1500	\$1500	0	0	0
Overlap Cost, \$/yr	\$4320	\$2160	\$2160	\$10,000	\$5000	\$5000
Overlap Cost, \$/a/yr	\$1.44	\$0.72	\$0.72	\$0.50	\$0.25	\$0.25
GPS net benefit		-\$0.29	\$0.52		\$0.30	\$0.10

<sup>1</sup> Annualized using a sinking fund approach (Hunt, 1995) with a 10% discount rate.

<sup>2</sup> Foam cost calculation assumed 0.007 gal./a with the producer buying lower quality foam at \$18/gal and the custom operator purchasing the higher quality at \$21/a.

<sup>3</sup> Annual cost is the sum of annualized cost of investment and recurring cost.

<sup>4</sup> Acreage assumed is 1500 acres for the producer and 20,000a/yr for the custom applicator. The producer is assumed to cover the acreage twice with either a fertilizer spreader or sprayer.

<sup>5</sup> Opportunity cost for sprayer operation assumes average custom rate for the producer at \$4.40/a (Doster et al., 1999) and a \$5/a custom charge.

<sup>6</sup> Extra chemical and fertilizer assumes that the operators are very cautious and only overlaps occur with a chemical or fertilizer cost of \$10/a.

This is a conservative estimate of GPS guidance benefits, which does not include many of the advantages outline above, shows that for the custom operator and the producer who already owns a GPS, the GPS guidance is profitable. In this example, the producer who does not own a GPS would need about 2000 acres to breakeven.

Sensitivity testing shows that for the producer with a GPS, the breakeven acreage for the lightbar is only 600 a. Of course, relatively few 600 acre farmers already have GPS. The breakeven acreage for the custom operator buying the complete system in this example is about 15,000 a. For the custom operator who uses the basis GPS guidance the breakeven acreage is only about 5000 a.

The custom operator example does not include a value for the fertilizer or chemical saved by fewer overlaps because typically such savings goes to the producer client, not to the custom applicator. Fewer skips and overlaps may be an important way for a custom applicator to retain current customers and gain new ones.

### **Auto-steering**

The next step in guidance technology is probably auto-steering.

“Even with the lightbar, almost nobody can keep an applicator on the swath all day. Operators get tired.” Azbell said. “Auto-steering would take over driving along the swath, with the operator turning at the ends.”

Some auto-steering technology is already commercially available for earth moving and open pit mining. For agriculture, legal liability is a key question. Who is responsible if the auto-steered equipment damages property or hits an animal or child? It is one thing to operate with auto-steering on a major construction site or in an open pit mine where access is controlled. It is another problem to operate on farm land where neighbors may object and others may have access to the land. This is especially true in areas with a substantial non-farm rural population.

“We have to have a kill switch, so that the operator can stop quickly if a problem occurs,” Azbell said.

## Argentina

Rapid adoption of GPS guidance systems is not limited to the US. About 300 guidance systems were in use in Argentina for the 1998-99 crop season, according to Mario Bragachini coordinator of the precision agriculture program at the National Institute for Agricultural Technology in Argentina. About 40% of those were on ground equipment.

Bragachini said that GPS guidance systems are popular in Argentina because they help reduce skips and overlaps, facilitate night spraying and substantially reduce labor requirements. Few Argentinean chemical applicators use foam markers. Before GPS guidance systems, spraying typically involved a crew of two or three, an equipment operator and one or two flaggers. With GPS only the equipment operator is needed and the risk of exposing flaggers to chemicals is eliminated.

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